Designer, Contractor, and Owner Views on the Topic of Design for Construction Worker Safety

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ABSTRACT

The construction industry is one of the largest and most dangerous industries in the US, where in 2009 the industry accounted for 834 deaths; more than any other industry. The incidence rate of 9.9 deaths per 100,000 workers puts the construction industry in fourth place behind the Agriculture/Forestry/Fishing/Hunting, Transportation/Warehousing, and Mining sectors (BLS 2011). The cause of a large number of these construction deaths can be attributed to factors that are distant from the construction site. A European study has shown that 60% of fatal accidents in construction are caused by decisions made "upstream" from the construction site (European Foundation 1991). Similarly, an Australian study showed that 63% of fatalities and injuries are attributed to a lack of planning and design decisions (NSW Workcover 2001), while in the US, Behm found that 42% of construction site fatalities can be linked to design (Behm 2005).

With such overwhelming evidence, foreign governments have initiated efforts to make designers aware of the impact of their decisions and design choices. These efforts include new legislation and improved guidelines (EEC 1992; NSW Workcover 2001) that aim to reduce the construction hazards linked to design. In the US, designers are mostly unaware of the concept of Design for Construction Worker Safety (DCWS), or even that their design decisions can affect the safety of the construction workforce. Professional organizations regularly resist change and refuse to even consider participating in the DCWS concept that would eventually assist in the improvement of construction site working conditions (Toole 2011).

The research presented in this paper represents the results gathered from a survey of the opinions of the primary construction industry participants (owners, designers, and contractors) on the topic of DCWS. The population of the survey was obtained from four different groups. Contractors who responded to the survey were randomly selected from the Associated General Contractors of America (AGC) directory. Designers were randomly selected from two sources: the American Institute of Architects (AIA) directory and the American Council of Engineering Companies (ACEC) directory. To represent owner organizations, the researchers chose to include university representatives who participate in the construction of

facilities on US university campuses. Through the survey, the authors investigate the extent of the acceptance of DCWS by industry participants, their opinions and identification of perceived obstacles or enablers of the concept, and the types of safety measures or safety plans they currently implement. The results of this research will assist construction professionals in determining the framework for a successful implementation of DCWS in the US construction industry. The implementation of DCWS by US professionals in their designs is important in an international construction market. Since DCWS is part of the design process in other countries, US designers wishing to practice in locations where DCWS is enforced by legislation, will find themselves at a disadvantage.

Key Words
Prevention through Design, Design for Construction Worker Safety, Survey, Owners, Contractors, Designers

INTRODUCTION

The completion of any construction project requires contributions from several entities that need to collaborate, preferably in harmony. These entities can be separated into three major groups: Owners, Designers, and Construction Contractors. As the first step needed to bring any construction venture to reality, owners come up with an idea or a need for a project to be constructed. Owners then assign designers with the task of transferring their idea into a tangible set of instructions to be used by construction contractors, the third entity, to bring the project to completion. The above description of the process is very simplified. In reality, the steps to construct a project from conception to completion can be very complicated and require a tremendous amount of work hours from all parties involved. Furthermore, several project delivery methods exist with combinations of responsibilities and tasks from all parties. These characteristics increase the complexity of the project, and also the construction industry.

While the complexity extends to many aspects of a project, in some cases traditional practice has simplified the process. One example is construction worker safety. The consideration of construction worker safety, at least in the US construction industry, has traditionally been left up to the construction contractors and their subcontractors. However, several countries have recently developed guidelines and legislation to expand the responsibility for addressing construction worker safety to other industry participants. These efforts follow the principles of Prevention through Design (PtD). According to the Prevention through Design website (Toole 2011), PtD is:

- Explicitly considering the safety of construction workers in the design of a project;
- Being conscious of and valuing the safety of construction workers when performing design tasks;
- Making design decisions based in part on how the project's inherent risk to construction workers may be affected; and
- Including worker safety considerations in the constructability review process.

The website also describes what is not PtD. According to the website (Toole 2011), PtD is not:

- Having designers take a role in construction safety **DURING** construction;
- An endorsement of future legislation mandating that designers design for construction safety;
- An endorsement of the principle that designers can or should be held partially responsible for construction accidents; and
- Implying that the vast majority of U.S. design professionals are currently equipped to design for construction safety.

With construction borders disappearing, US companies (designers and construction contractors) find themselves being key players in the construction industry of other countries. In many cases, the US companies will encounter these guidelines and legislation that are completely foreign to the US construction environment.

Background

One reason that a country might choose to enact legislation for engineers to practice PtD is the significant number of construction deaths and their connection to the design of the various projects. A European study concluded that 60% of fatal accidents in construction are caused by decisions made "upstream" from the construction site (European Foundation 1991). Similarly, an Australian study found that 63% of fatalities and injuries are attributed to a lack of planning and design decisions (NSW Workcover 2001).

In Europe, the European Union has developed a set of directives to address the issue of design related fatalities. The first directive, the Council Framework Directive 89/391/EEC (EEC 1989), introduced provisions and guidelines for worker safety and health by specifying obligations from the employers and workers in various topics such as prevention, training, worker consultation, etc. The provisions in Directive 89/391/EEC were further expanded into 19 other directives comprising a more extensive body of legislation. The 89/391/EEC directive instructed EU member countries to adopt it, and its subsequent directives, and at the same time repealed the local regulations that were in place in the local governments (Martínez Aires et al. 2010). The member countries were given until December 31, 1992 to draw up, enact, and enforce laws to make Directive 89/391/EEC active in all member states. This goal was not achieved by all of the countries, with only a few of them (Denmark, Sweden, France) actually meeting the December 1992 deadline. Finland was the last country of the EU15 to enforce the directive, which did not happen until 2002, ten years after the original deadline (Martínez Aires et al. 2010).

Specifically for construction, the EU produced Directive 92/57/EEC on temporary or mobile work sites, which places legal responsibilities on owners and those associated with the design of the work. Articles 4 and 5 of the 92/57/EEC directive instruct designers to practice PtD by appointing a project supervisor responsible for all aspects of safety and health during the stages of design and

preparation (EEC 1992). Article 14 of the directive instructs the member countries to *"…bring into force the laws, regulations and administrative provisions…"* (EEC 1992) by December 31, 1993. However, as with the previous directive, this did not occur. The only country that managed the task was Denmark. Austria and Belgium were the last countries of the EU15 to enforce the directive (Martínez Aires et al. 2010). The 92/57/EEC directive was translated into legislation in several of the member countries, with the most notable being the Construction (Design and Management) Regulations (CDM Regulations) in the UK in 2004 (later revised in 2007), and Spain's Royal Decree 1627/1997, titled "Minimum Provisions for Health and Safety at Construction Sites".

It is very difficult to evaluate how these measures have improved accident prevention in the European Union. Each member country has different definitions for characterizing a fatal workplace accident and when an injury is related to work conditions. The length of time after an accident in which a fatality is connected to the accident also differs between the countries. In addition, the level of reporting differs since some countries have "Universal Social Security Systems" while others have "Insurance – Based Systems"(Martínez Aires et al. 2010). A recent investigation conducted for NIOSH by researchers at Oregon State University and by researchers at Loughborough University in the UK investigated opinions of construction professionals in the UK on various topics that included project cost, duration, quality, productivity, and safety (Gambatese 2011). Conducted in 2010, the study was based on an on-line survey of 258 construction industry professionals, and 14 focus groups involving 110 construction industry professionals. Ninety percent of the survey respondents and 88% of the focus groups participants feel that PtD as implemented under the CDM Regulations has had a positive impact on construction worker health and safety.

The Australian National Occupational Health Strategy (2002 – 2012) sets eliminating hazards at the design stage as one of five national priorities. The strategy contains a requirement called *"duty of care"* which places requirements on all who have influence on the hazards in the work place (employers, owners, employees, designer organizations, and suppliers of equipment and materials) to take action to mitigate the hazards. The intent of the strategy is to require all to use reasonably practical means to identify the hazards and provide solutions within the constraints of the business environment (Landis Floyd et al. 2010).

Research on PtD has also been taking place in the US where researchers and industry professionals have been trying to promote the concept to more design and construction practitioners across the country. Additionally, initiatives by NIOSH and other government associations are attempting to investigate the best methods to implement PtD and to make PtD a norm in the construction industry (NIOSH 2011). The association of design features to construction site deaths has also been investigated in the US. In a study by Behm, 42% of construction site fatalities were linked to design (Behm 2005).

With all of the efforts by NIOSH and the individuals involved with PtD, the US construction industry is largely unaware of the concept. When knowledgeable about PtD, some industry individuals appear to be set against the concept's implementation in any form. This paper reports on the findings of a survey

conducted in the summer and fall months of 2011 that attempts to investigate the level of knowledge of PtD among industry participants in the US, their willingness to accept legislation similar to the CDM legislation in the UK, and identification of enablers and obstacles to PtD implementation in the US.

METHODOLOGY

For this research study, the PtD concept was introduced to the survey participants as "Design for Construction Worker Safety" (DCWS). While the concept is identified in literature as PtD, this distinction was made to differentiate it among all of the efforts related to PtD in other industries, and also to identify the focus on construction worker safety as opposed to end-user or maintenance safety.

Survey Structure and Questions

Three similar surveys were developed and sent to the following construction industry groups: Owners, Designers (Architects and Engineers) and Contractors. The surveys were designed to gather the respondent's views on the DCWS concept. An introductory page in each survey explained the research and defined the DCWS concept. The survey questions were geared to identify the level of knowledge regarding the concept of DCWS, and PtD in general, and to try to identify what the community feels are the enablers and obstacles to implementation of the concept in the US.

Each survey had four sections. The first section included questions regarding the type of work conducted within the respondent's firm and their personal work experience. The information solicited included the name of their organization, their title, years of experience in construction and design, types of project delivery methods their organization uses, and the types of structures and projects they construct or design. Respondents from design firms were asked to identify the types of building systems they design.

The second section of the survey aimed at identifying any previous knowledge the participants might have had about the DCWS concept, as well as any participation their firms/organizations might have had in DCWS in the projects they worked on. The participants were also asked to identify the reasons for their firm's decision to start participating in DCWS if applicable.

The third section of the survey included a series of Likert-type questions where the participants were asked to identify the level of their agreement or disagreement with statements regarding designers, owners, and safety in the construction industry in general. The statements addressed the level of knowledge of each group about construction site operations, their understanding of hazards to construction workers, capacities and opportunities for education in construction safety, and possible involvement in construction safety. The survey participants were asked to state their agreement on whether decisions made during project conception, design, and construction affect construction worker safety. They were also asked whether their firm would be supportive of legislation for designers to practice DCWS, and whether their firm would be supportive of the DCWS concept if designers were legally protected from liability in practicing DCWS.

The fourth section of the survey asked the participants to state if there are obstacles or enablers for designers to practice DCWS. If so, the respondents were asked to identify the obstacles and enablers.

Selection of Investigated States

To ensure geographic diversity among participants, the researchers used the nine US Census Bureau divisions (USCB 2011) as illustrated in Figure 1. At least half of the states from each division were randomly chosen, and a total of 29 states were used in the study. Specifically the US Census Bureau divides the country into nine divisions, which are:

- *Pacific*: Alaska, California, Hawaii, Oregon and Washington;
- *Mountain*: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming;
- *West North Central*: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota;
- *West South Central*: Arkansas, Louisiana, Oklahoma and Texas;
- *East North Central*: Illinois, Indiana, Michigan, Ohio and Wisconsin;
- *East South Central*: Alabama, Kentucky, Mississippi and Tennessee;
- *New England*: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont;
- *Middle Atlantic*: New Jersey, New York and Pennsylvania; and
- *South Atlantic*: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia and West Virginia.

The states selected for the study were Alaska, Arkansas, Colorado, Connecticut, Delaware, Georgia, Idaho, Illinois, Kansas, Kentucky, Maine, Maryland, Missouri, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Virginia, Washington, and Wisconsin. A map of the US showing the selected states for the study is shown in Figure 2.

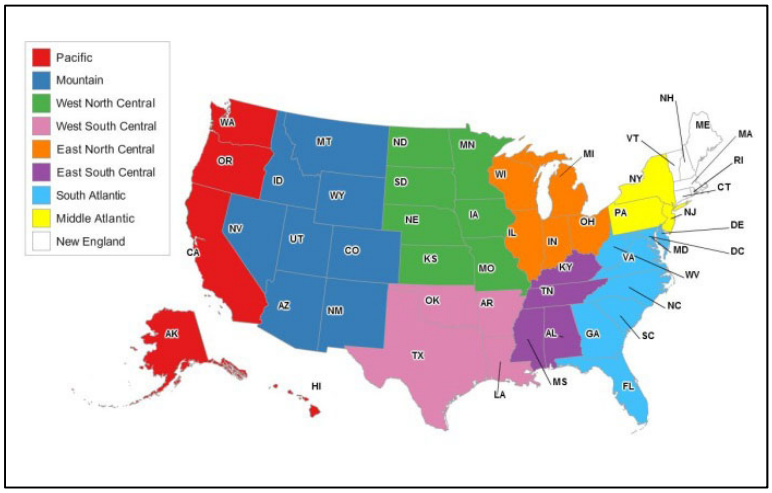

Figure 1. US Census Bureau Divisions

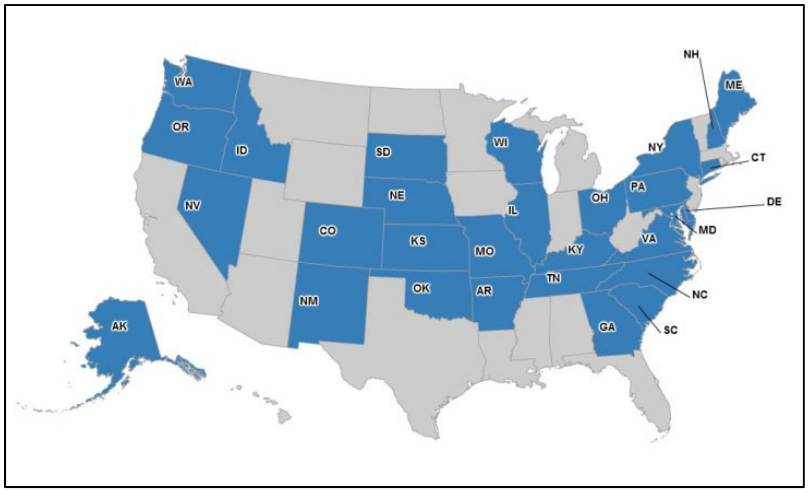

Figure 2. Randomly Selected States for the Study

Owner Population Selection

Attempts were made to distribute the "Owner Survey" to owner groups in the US, but none of the contacted organizations were willing to distribute the survey to their members. As a result the researchers decided to concentrate on a particular type of owner, that being facilities services within major universities. Universities in the US, depending on their size, perform multiple construction projects at any given time. The types of projects include a variety of facilities ranging from educational and residential buildings, to power plants, research facilities, sports facilities, and hospitals. The universities also have experience with a variety of project delivery methods which include, among others, design-bid-build, design-build, CM/GC, build-operate-transfer, etc.

The researchers used Peterson's Student Edge website (Peterson's 2011) to obtain a directory of all the universities in the US. Among other criteria, the universities in the directory are stratified according to their state and the size of their student body. The website separates universities into four different size categories:

- **Large Universities**: Universities with more than 15,000 students
- **Mid-Sized Universities**: Universities with between 5,000 and 15,000 students
- **Small Universities**: Universities with between 2,000 and 5,000 students
- **Very Small Universities**: Universities with a less than 2,000 students

For the purposes of this research "Very Small Universities" were not surveyed. For all other universities in the 29 selected states, a contact person within the office of facility services or any other university department that would be responsible for the supervision and management of construction contracts on their respective campus was identified. A total of 554 universities were identified in the sampled population, and personnel from 346 (62%) of these universities were contacted.

Contractor Population Selection

The sample population for contractors was obtained from the Associated General Contractors of America website (AGC 2011). The website maintains a directory of construction companies and for the purposes of this investigation general contractors were selected that participate in commercial, healthcare, manufacturing, education, and lodging/multi-family residential projects. Attempts were made through internet searches to identify a contact person within each construction firm to respond to the survey. Targeted participants were those who would have extensive construction experience and are a key management figure in their firm. There were 1,617 firms identified from the 29 selected states, and personnel from 937 (58%) of these were contacted.

Designer Population Selection

The sample population for designers (design engineers) was obtained from the American Council of Engineering Companies website (ACEC 2011). The website maintains a directory of engineering companies practicing in the US and is stratified according to size and state. The directory also allows visitors to the website to filter the companies according to the market served. For this study the researchers filtered the list according to the markets that are used in the construction of buildings, the main area of interest in the study, such as "Barracks", Dormitories", "Civil Buildings", etc. The website separates firms into six different sizes which are listed below:

- Small Firms: 1 – 30 employees,
- Medium Firms: 31 – 75 employees
- Medium Large Firms: 76 – 150 employees
- Large Firms: 151 – 499 employees
- Extra Large Firms: 500 – 999 employees
- Extremely Large Firms: more than 1000 employees

Attempts were made through internet searches to identify a contact person within each design firm to respond to the survey who would have extensive design experience and be a key management figure in their firm. There were 2,131 firms identified from the 29 selected states in all six firm sizes, and personnel from 1,291 (61%) of these were contacted.

Architect Population Selection

The sample population for the architects was obtained from the online database of the American Institute of Architects (AIA 2011). The database stratifies architects by state. Due to the large number of architects registered within the AIA directory, a random sample was generated for each state, and a survey was sent to each selected architect. A total of 1,080 architects were contacted from the 14,905 registered AIA architects in the US (7%).

Survey Distribution

The surveys were administered online using a survey tool called Limesurvey, which is a computer program administered by the Oregon State University School of Engineering. All of the survey responses were stored on University servers and downloaded for analysis. Identifying information from the participants was stripped during analysis of the data.

RESULTS

Of the 3,654 individuals who were contacted for the various surveys, 765 responded. The messages for 116 of these individuals came back as undeliverable suggesting the contact information was incorrect, and these contacts were not used in the calculation of the response rates. The response rate for all the surveys was 21.6%, and this information is shown in Table 1. The distributions of responses from each state and for each sampled group are shown on Figure 3.

Table 1. Summary of Responses and Response Rates

	Owners	Architects	Engineers	Contractors	Total
Responses	121	221	244	179	765
Contacted	346	1080	1291	937	3654
Undeliverable	1	21	48	46	116
Response Rate	35.1%	20.9%	19.6%	20.1%	21.6%

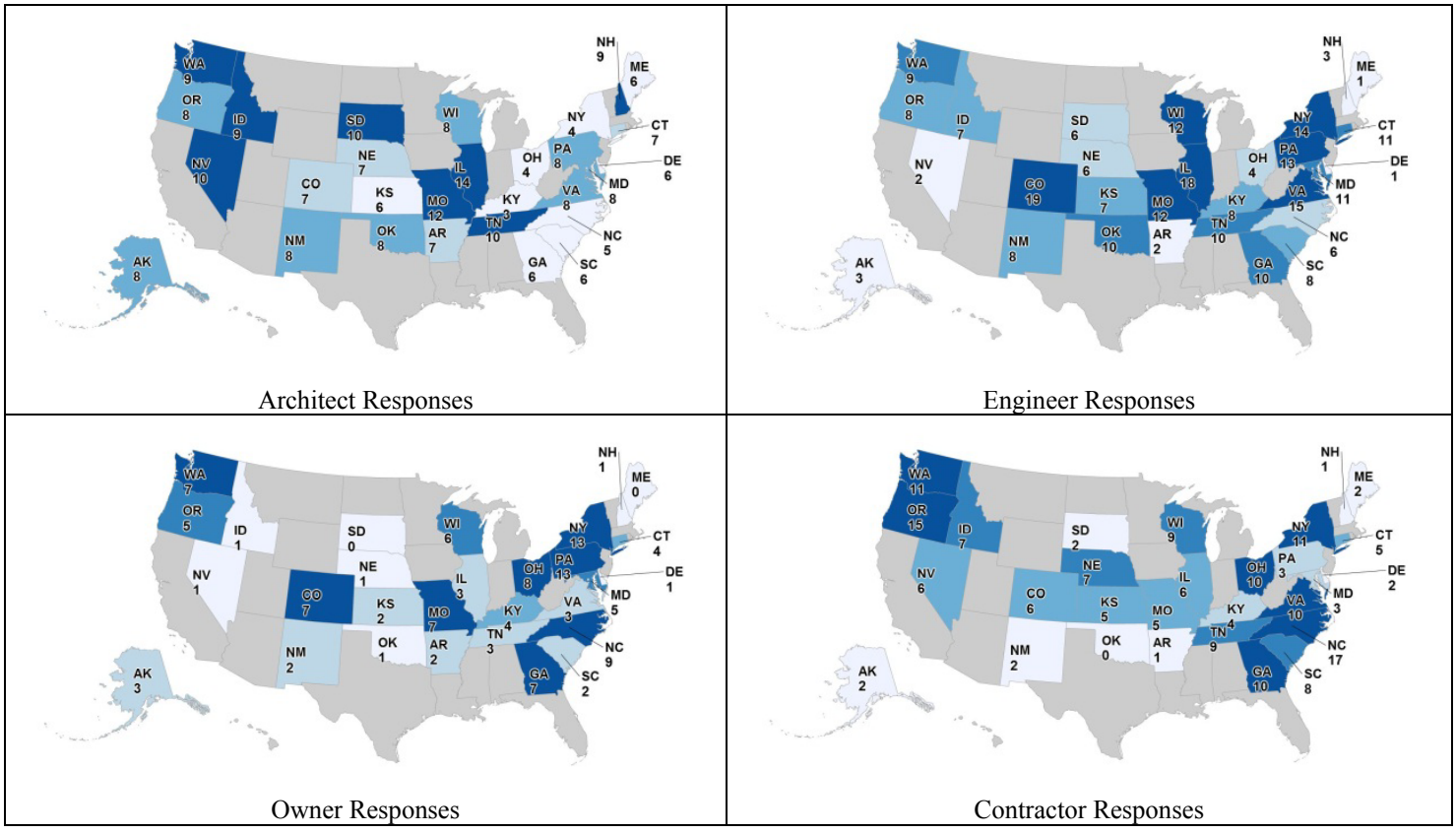

Figure 3. Distribution of responses from each sampled state

The survey participants had extensive experience in construction, and that can be observed with the years of practice they had in the industry. Table 2 shows that 73.0% of all engineer participants, and 79.2% of architects, have more than 20 years of experience in design. On the construction side, 81.1% of contractor participants have an equivalent experience of more than 20 years in construction.

Table 2. Experience in Design and Construction by Survey Participants

	Engineers		Architects		Contractors			
	In Design		In Design		In Construction		Total	
NA	4	1.6%	3	1.4%	1	0.6%	8	1.2%
0 - 5 years	12	4.9%	7	3.2%	6	3.4%	25	3.9%
6 - 10 years	10	4.1%	5	2.3%	3	1.7%	18	2.8%
11 - 15 years	18	7.4%	12	5.4%	16	8.9%	46	7.1%
16 - 20 years	22	9.0%	19	8.6%	8	4.5%	49	7.6%
21 - 25 years	37	15.2%	34	15.4%	29	16.2%	100	15.5%
26 - 30 years	56	23.0%	39	17.6%	35	19.6%	130	20.2%
more than 30	85	34.8%	102	46.2%	81	45.3%	268	41.6%
	244	100.0%	221	100.0%	179	100.0%	644	100.0%

Survey participants had some previous knowledge of the DCWS concept. Specifically, 20.5% of engineers, 5.4% of architects, 21.5% of owners, and 16.2% of contractors stated that they knew about DCWS prior to the survey. When the designers (architects and engineers) were asked to state if their firm is practicing some form of DCWS, only 19.3% of engineers and 5.4% of architects stated that their firm is practicing some form of DCWS. Examples of their efforts included: active practice of PtD through focused project reviews and project hazard registers, and the use of construction personnel during the early design process to incorporate means and methods into the design.

When asked if their firm has guidelines for reviewing their designs for construction worker safety, 9.8% of engineers and 3.2% of architects stated that they did. The designers were also asked to state if their firm has been asked to address issues related to construction worker safety. Thirty-one percent of engineers and 10.4% of architects confirmed that their firm has been asked to address safety.

One notable observation from the survey responses is that all of the industry participants recognize that decisions made in the project stages prior to the beginning of construction can affect the safety of workers during construction. This is supported by the following survey results:

- Regarding their level of agreement with the statement, "Decisions made **before the design** of a project begins can help eliminate some construction hazards", 68.4% of the engineers, 47.5% of the architects, 59.5% of the owners, and 81.0% of the contractors stated that they either agree or strongly agree with the statement.

- In response to the statement, "Decisions made **during the design** of a project can help eliminate some construction worker hazards", 77.9% of the engineers, 52.5% of the architects, 66.2% of the owners, and 86.6% of the contractors stated that they either agree or strongly agree with the statement.
- In response to the statement, "Decisions made **during construction** of a project can help eliminate some construction worker hazards", 86.5% of the engineers, 84.2% of the architects, 80.2% of the owners, and 92.2% of the contractors stated that they either agree or strongly agree with the statement.

A summary of the above results related to their opinion about construction worker safety is shown in Table 3.

Table 3. Opinions on Whether Decisions Made During Various Project Phases Affect Construction Worker Safety

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Before Design	Engineers	12.3%	56.1%	16.4%	3.7%	0.4%
	Architects	5.0%	42.5%	29.9%	6.8%	6.8%
	Owners	7.4%	52.1%	25.6%	2.5%	1.7%
	Contractors	24.6%	56.4%	10.6%	2.8%	1.7%
During Design	Engineers	12.7%	65.2%	8.6%	2.5%	0.4%
	Architects	4.5%	48.0%	25.8%	6.8%	6.3%
	Owners	8.3%	57.9%	20.7%	1.7%	0.8%
	Contractors	28.5%	58.1%	6.7%	0.6%	1.7%
During Construction	Engineers	36.9%	49.6%	2.5%	0.8%	0.0%
	Architects	36.7%	47.5%	5.9%	0.9%	0.5%
	Owners	28.1%	52.1%	7.4%	1.7%	0.0%
	Contractors	45.3%	46.9%	2.2%	0.0%	1.7%

Even though the majority of industry professionals recognize that their design decisions influence construction site safety, willingness to support legislation similar to the CDM Regulations in the UK was not expressed in the survey. Specifically, when asked if they think that their firm/organization would be supportive of legislation for designers to start practicing DCWS, only 15.6% of engineers, 10.4% of architects, 11.6% of owners, and 38.0% of contractors responded that their firm/organization would be supportive.

The researchers hypothesized that a major obstacle for designers to practice DCWS is the fear of litigation. For that reason, the researchers asked the survey participants whether their firm/organization would be supportive of DCWS if designers were legally protected from liability associated with practicing DCWS. The response for support of the DCWS concept was 53.3% from engineers, 42.5% from architects, 21.5% from owners, and 31.8% from contractors.

The survey participants were also asked if designers and owners should be involved in construction worker safety. As seen in Table 4, support for designers to be involved in construction worker safety was 53.7% from engineers, 25.8% from architects, 45.4% from owners, and 79.9% from contractors. The support for owner involvement was 52.9% from engineers, 27.2% from architects, 59.5% from owners,

and 65.4% from contractors. With the exception of the architect group, there seems to be significant support for more universal involvement of the project team members in construction safety.

Table 4. Responses on Support of Owners and Designers to be involved in Construction Worker Safety

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Designers should be involved in construction worker safety	Engineers	12.7%	41.0%	20.1%	9.8%	7.8%
	Architects	6.8%	19.0%	31.2%	18.1%	17.2%
	Owners	10.7%	34.7%	29.8%	13.2%	2.5%
	Contractors	25.7%	54.2%	10.1%	3.9%	1.7%
Owners should be involved in construction worker safety	Engineers	12.7%	40.2%	18.0%	11.9%	5.3%
	Architects	5.9%	21.3%	24.4%	19.0%	21.3%
	Owners	19.0%	40.5%	18.2%	7.4%	4.1%
	Contractors	21.8%	43.6%	16.2%	10.1%	3.9%

The survey participants were also asked to add any comments and input to guide future implementation of the DCWS concept by the US construction industry. Several respondents commented on the need for more education on the DCWS concept, especially in the university environment. Some of the participants also stated that there is an increasing need for collaboration between designers, contractors, and owners, and once that is achieved then DCWS will be more easily accepted by designers. Alternative delivery methods such as design-build and CM/GC allow this increased collaboration between construction groups, and the practice of DCWS could be more easily implemented under such contracting arrangements.

The study participants also commented that increased government regulation and legislation would not be beneficial for the industry and that legislative efforts for DCWS will not get support from the industry. Designers in particular stated that an additional review of designs for safety will increase their costs and commented that owners would not be willing to pay for that increase. Some participants also stated that the highly litigious nature of the US construction industry does not encourage designers to participate in construction safety.

Lastly, several designers and owners indicated concern that design costs might increase if an additional review was added to the design process to account for construction worker safety. This concern is valid since that additional review is presently not covered in designer fees. They also feel that owners may not be willing to compensate them for that additional work.

CONCLUSIONS

Design and construction participants clearly understand that design decisions affect construction worker safety. However, that understanding alone is not enough to cause designers to participate in DCWS. The highly litigious nature of US society and of the US construction industry is a deterrent for any individual to accept additional responsibility and risk. Study results indicate that the fear of litigation is a major restraining factor for designers to practice DCWS. The framework for a

possible implementation of DCWS within the construction industry should take that into consideration and protect designers from frivolous law suits.

Education of designers about DCWS is important. As observed in the survey results, the majority of the construction industry participants did not have any previous knowledge of the concept. It is imperative that universities with civil engineering and architecture degree programs include courses in their curricula that address the issue of construction safety, and the effect design decisions have on construction worker safety. Additionally, practicing engineers and architects must be educated in the concept through seminars and professional development courses.

Increased collaboration between project participants should also be encouraged. Construction contractors have inherent knowledge concerning safety and constructability issues that can only be shared through dialogue with owners and designers. Traditional project delivery methods inhibit this flow of knowledge. Alternative project delivery methods (such as Design-Build and CM/GC) break communication barriers and, as a result, DCWS will gain more acceptance from participants who practice these types of contracting methods.

To address the issue of increased design costs, further research is required in measuring the life cycle project costs of implementing DCWS in projects. The increased initial design costs might prove beneficial in eliminating construction and maintenance costs in a projects lifetime, which extends beyond the construction phase until the facility's eventual decommissioning.

The US construction industry can be slow in adapting to new methods of doing business. Safety should not be part of that trend. As mentioned previously, other countries consider construction site safety so important that they proposed and adopted legislation for designers to start practicing DCWS and PtD. US designers and contactors will need to adapt if they would like to venture and participate in construction projects abroad.

STUDY LIMITATIONS AND FUTURE WORK

Further analysis of the information gathered from the surveys is required in order to determine if there are correlations between participant characteristics and responses. Examples of these include the correlation between DCWS acceptance, with the years of experience, project delivery methods, project types, as well as geographic location.

The low response rate (21.6%) makes the generalization of the responses to the rest of the country difficult. Moreover, the "Owner" group that responded to the surveys is very unique and their responses might not be generalized to all other types of owners in the US with much confidence. Further study is needed to find how other owners feel about the topic of DCWS and PtD in general. Target groups for such a study could be owners of manufacturing/industrial facilities in several industries, owners of energy generation plants, and land developers, to name a few.

Administering the survey online limited the collection of in-depth opinions, comments, and strategies concerning possible future implementation frameworks for DCWS. That information can be collected through focus groups consisting of design and construction professionals.

REFERENCES

ACEC (2011). "ACEC Organization Directory." Retrieved 11/8/2011, 2011, from http://www.acec.org/.

AGC (2011). "The Associated General Contractors of America - Member Directory." Retrieved 11/8/2011, 2011, from http://directory.agc.org/search/search.aspx.

AIA (2011). "The American Institute of Architects - Find an Architect." Retrieved 11/8/2011, 2011, from http://architectfinder.aia.org/.

Behm, M. (2005). "Linking construction fatalities to the design for construction safety concept." Safety Science **43**(8): 589-611.

BLS (2011). Census of Fatal Occupational Injuries, 1922-2009. Washington DC, US Bureau of Labor Statistics.

EEC (1989). Council Directive on the introduction of measures to encourage improvements in the safety and health of workers at work. 89/391/EEC. EEC. Brussels, Belgium, EEC. **89/391/EEC**.

EEC (1992). Council Directive on the implimentation of minimum safety requirements at temporaty or mobile construction sites. 92/57/EEC. EEC. Brussels, Belgium, EEC. **92/57/EEC**.

European Foundation (1991). Dublin, The European Foundation for the improvement of Living and Working Conditions (EF/88/17/FR)

Gambatese, J. (2011). Findings from the Overall PtD in UK Study and Their Application to the US. Prevention through Design - A New Way of Doing Business: Report on the National Initiative, Washington, DC.

Landis Floyd, H. and D. P. Liggett (2010). "Hazard Mitigation Through Design." Industry Applications Magazine, IEEE **16**(3): 17-22.

Martínez Aires, M. D., M. C. Rubio Gámez and A. Gibb (2010). "Prevention through design: The effect of European Directives on construction workplace accidents." Safety Science **48**(2): 248-258.

NIOSH (2011, Nov 1, 2011). "CDC - Prevention through Design - NIOSH Workplace Sefety and Health Topic." Retrieved Nov 15, 2011, 2011, from http://www.cdc.gov/niosh/topics/ptd/.

NSW Workcover (2001). CHAIR, Safety Design Tool.

Peterson's (2011). "StudentEdge." Retrieved 11/8/2011, 2011, from http://www.studentedge.com/studentedge/.

Toole, M. (2011). "Prevention through design, Concept." Retrieved November 25, 2011, 2011, from http://www.designforconstructionsafety.org/concept.shtml.

Toole, T. M. (2011). "Internal Impediments to ASCE's Vision 2025." Leadership and Management in Engineering **11**(2): 197-207.

USCB (2011). "Economic Census: Regions and Divisions." Retrieved 11/8/2011, 2011, from http://www.census.gov/econ/census07/www/geography/regions_and_divisions.html.